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subjected to a stand-up blast. In this case the layers are artificially conceived based on the intended blast outcome rather than corresponding to physically distinct strata of the material being blasted.

In the case that the blast field comprises plural strata of material of distinct characteristics, the layers will typically correspond to the strata since the blast outcomes associated with the present invention are then usually specific to each individual stratum. By way of example, the blast field may comprise a coal seam (stratum) extending beneath overburden. In this simple case the layers correspond respectively to the strata of coal and overburden. The first aspect of the invention will be described in more detail with reference to strata of material, but is not limited thereto.

In an embodiment of this first aspect, the method involves blasting plural strata of material including a first body of material comprising at least of first stratum of material and a second body of material comprising at least a stratum of overburden over the first body of material. The present invention therefore provides in this embodiment a method of blasting plural strata of material including a first body of material comprising at least a first stratum of material and a second body of material comprising at least a stratum of overburden over the first body of material in a blast field having at least one free face at the level of the second body of material, the method comprising drilling blastholes in the blast field through the second body of material and, for at least some of the blastholes, at least into the first body of material, loading the blastholes with explosives and then firing the explosives in the blastholes in a single cycle of drilling, loading and blasting at least the first and second bodies of material, wherein the first body of material is subjected to a stand-up blast in said single cycle and said second body of material is subjected to a throw blast in said single cycle whereby at least a substantial part of the second body of material is thrown clear of the blast field beyond the position of said at least one free face.

More generally, differential blast outcomes, specifically in the first aspect of the invention differential forward movement of the material, are achieved for different layers of material. In one embodiment, the first aspect of the invention involves the use of blasts that combine

blastholes through the second body of material and, for at least some of the blastholes, at least into the first body of material, loading the blastholes with explosives and then firing the explosives in the blastholes in a single cycle of drilling, loading and blasting at least the first and second bodies of material, wherein the second body of material is subjected to a blast of different design including at least different inter-row blast hole delay times and/or different inter-hole blast hole delay times in any one row to that of the first body of material, resulting in a different blast outcome in the second body of material to that in the first body of material.

In this second aspect of the invention the term "layers" (and variations thereof) has the same intended meaning as described above in connection with the first aspect of the invention.

A reference to "inter-hole" herein is to the blastholes in any one row of blastholes. The distance between blastholes in any one row is known as the spacing. The distance between rows of blastholes is known as the burden, and the burden is generally less than the spacing. Usually, where the blastfield has a free face, the rows of blastholes will extend substantially parallel to the free face. The blastholes in any one row need not be exactly aligned but may be offset from each other or from adjacent blastholes in the row.

In one embodiment of this second aspect, the method involves blasting plural strata of material including a first body of material comprising at least of first stratum of material and a second body of material comprising at least a stratum of overburden over the first body of material. The present invention therefore provides in this embodiment a method of blasting plural strata of material including a first body of material comprising at least a first stratum of material and a second body of material comprising at least a stratum of overburden over the first body of material, the method comprising drilling rows of blastholes through the second body of material and, for at least some of the blastholes, at least into the first body of material, loading the blastholes with explosives and then firing the explosives in the blastholes in a single cycle of drilling, loading and blasting at least the first and second bodies of material, wherein the second body of material is subjected to a

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blast of different design including different inter-row blasthole delay times and/or different inter-hole blasthole delay times in any one row to that of the first body of material, resulting in a different blast outcome in the second body of material to that in the first body of material.

The second body of material may consist essentially of the stratum of overburden. In this case, in both the first and second aspect of the invention, the explosives in the second body of material are usually spaced from the bottom of the second body of material. As described with reference to the first aspect, in the second aspect of the invention a third body of material may be disposed between the first and second bodies of material, the third body of material comprising at least one stratum of burden and/or recoverable mineral, with the third body of material being subjected to a blast in said single cycle of different design to the blast to which the first and/or second bodies of material are subjected in said single cycle.

In the embodiment of blasting plural strata in either of the first and second aspects of the invention, the first body of material may comprise at least two strata of recoverable mineral and at least one stratum of interburden therebetween. In this case the explosives in the first body of material are usually disposed only in the at least one stratum of interburden. Also, the explosives in the interburden are generally spaced from the strata of recoverable mineral. In this embodiment the blastholes are typically not drilled into the lowermost strata of recoverable mineral in the first body of material. The explosives in each of at least some of the blastholes in the interburden may be provided as a main column of explosives and as a relatively small deck of explosives spaced from and beneath the main column. In this case the relatively small deck of explosives is usually fired on a different delay to the main column.

In either of the first and second aspects of the invention, any blasthole that does not extend into the first body of material may, but need not, extend to the bottom of the second body of material and the phrase "through the second body of material" shall be construed

accordingly.

In the second aspect of the invention, and depending upon the desired different blast outcomes between the bodies of material, the blast field may not have a free face, or may have a partial free face.

As noted above, the differential outcomes in the second aspect of the invention may comprise a throw blast in the second body of material and a stand-up blast in the first body of material and for convenience the second aspect of the invention will hereinafter be described with these differential outcomes in mind. In this case, to achieve throw of the second body of material, the second body of material has an associated free face in the intended throw direction. Other aspects of the first aspect of the invention described hereinbefore may also apply individually or in combination to the second aspect of the invention, and vice versa.

In another embodiment of either of the first and second aspects of the invention, the explosives in each of at least some of the blastholes in the second body of material may be provided as a main column of explosives and as a relatively small deck of explosives spaced from and beneath the main column. Here the relatively small deck of explosives generally is fired on a different delay to the main column.

Generally, in either of the first and second aspects of the invention not all of the blastholes in the second body of material extend into the first body of material. In this case typically at least some of the blastholes in the second body of material do not extend to the bottom of the second body of material.

In either of the first and second aspects of the present invention the first body of material may be buffered in the direction of throw defined by the throw blast of the second body of material, as described herein. The buffering may be at least partly provided by material from the second body of material thrown in a throw blast in said single cycle. Here the portion of the second body of material designed to provide the buffering material for the

first body of material is usually adjacent at least one free face and is divided into layers by respective decks of explosives in the blastholes in said portion of the second body of material, and all the decks of explosives in any one layer of said portion are fired before any deck in a layer of said portion beneath said one layer.

The explosives in blastholes in the first body of material may be initiated from the back of the blast (remote from the location of the free face) towards the front of the blast (adjacent the location of the free face).

It is also possible that the explosives in blastholes in one or both of the first and second bodies of material may have an initiation point remote from edges of the blastfield. It is further possible that the blast in said one or both of the first and second bodies of material may proceed in multiple directions from said initiation points.

In one embodiment of the first or second aspect the blast field has a free face at the level of the second body of material and the explosives in blastholes in the second body of material adjacent the back of the blast (remote from the location of the free face) are initiated before the explosives in blastholes in the second body of material further forward (closer to the location of the free face).

In another embodiment of the first or second aspect, in said single cycle the blast in the first body of material is initiated after initiation of the blast in the second body of material. The delay between initiation of the throw blast in the second body of material and initiation of the stand-up blast in the first body of material is typically about 40 seconds or less, preferably in the range of about 500 to 25000 ms. In an alternative embodiment of the first or second aspect, in said single cycle the blast in the first body of material is initiated before initiation of the blast in the second body of material.

In a variation of the invention said loading and blasting in said single cycle are preceded by blast hole logging to determine the location of any stratum of recoverable mineral in

each blasthole. The blasthole logging may comprise gamma-ray logging.

In the first aspect of the invention, differential blast design features for achieving the throw blast in the second body of material and the stand-up blast in the first body of material may be selected from one or more of blasthole pattern, explosive type, explosive density, blasthole loading configuration, explosive mass, powder factor, stemming, buffering and explosive initiation timing.

Where the blastholes in the blastfield are disposed in plural rows extending substantially parallel to the at least one free face, the blast in the first body of material may have different inter-hole delays in any one row and/or different inter-row delays to the blast in the second body of material.

In the second aspect of the invention, differential blast design features between the blast in the second body of material and the blast in the first body of material may be additionally selected from one or more of blasthole pattern, explosive type, explosive density, blast hole loading configuration, explosive mass, powder factor, stemming and buffering.

By way of example, where the blasting is for the recovery of coal and the second body of material is overburden, the following blast design parameters may apply:

> The "throw-blast" design may have, but not be restricted to, powder factors in the range 0.1-1.5 kg/m^3 (mass of explosive per unit volume of rock – typically 0.4-1.5 kg/m^3), blasthole spacings and burdens in the range 2 m-20 m (typically 5 m-15 m), blasthole depths in the range 2 m-70 m and any explosive type, density or loading configurations used in normal blasting operations, such as ANFO blends, densities in the range 0.1 – 1.5 g/cm^3 and bulk pumped, augured, packaged or cartridged explosives. The inter-hole delays may be in the range 0-40000 ms, preferably, 0-100 ms, more preferably 0-45 ms and typically 1-30 ms, and the inter-row delays may be in the range of 0-40000 ms, preferably 0-2000ms and typically 30-500 ms. The "throw-blast" portion of the blastholes will generally

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fire before the "stand-up" portion of the blastholes, with a separation in time in the range of 0-40000 ms, preferably 0-30000 ms, more preferably 100-25000 ms and typically 500-5000 ms. The "throw-blast" design will preferably have a complete or partial free face and substantially open void in front to allow the material to be thrown into the void.

The "stand-up" blast design may have, but not be restricted to, powder factors in the range 0.02-1.5 kg/m^3 (mass of explosive per unit volume of rock – but typically in the range 0.05-0.8 kg/m^3 and sometimes restricted to 0.05-0.4 kg/m^3), blasthole spacings and burdens in the range 2 m-20 m (typically 3-15 m), blasthole depths in the range 2 m-70 m and any explosive type, density or loading

Figure 4 illustrates a third particular embodiment of the method of the invention;

Figure 5 illustrates a fourth particular embodiment of the method of the invention;

Figure 6a and 6b are plan and cross-sectional views, respectively, of a blast as described in the Example, which is in accordance with the embodiment of Figure 5; and

Figure 7 illustrates a blast in accordance with the invention which achieves a differential fragmentation outcome; and

Figure 8 is a plan view similar to Figure 6a, but of another blast in accordance with the invention.

Figure 1 illustrates a generalised concept for blasting two or more layers of material in accordance with the first invention. A first body 10 of material is shown as extending beyond a free face 12 of a second body of material 14. However, as in the embodiments of Figures 2 to 4, the free face 12 may extend to the bottom of the first body 10.

In the embodiment shown the first and second bodies (10, 14) of material may be of the same or different material. Thus, the second body of material may comprise burden or recoverable mineral (e.g. coal, ore), and the first body of material may comprise burden or recoverable mineral (e.g. coal, ore). Similarly, the first and second bodies of material may comprise materials having the same or different characteristics. For example, the first and second bodies of material may comprise predetermined regions of the same geological formation, or regions within a formation that have different geological characteristics e.g. hardness. Generally, but not necessarily, the second body 14 will be of one or more strata of overburden, while the first body 10 will have a stratum of recoverable mineral immediately (such as coal) below the second body 14, for example as illustrated in Figure 4. However, at least a second stratum of recoverable material may be disposed as the lowermost stratum of the first body 10 with interburden between the or each two adjacent strata of recoverable mineral, as shown in Figures 2 and 3.

between groups of ten holes. The first group of holes initiates 150 ms after the first hole in row B.

Stratum 3: Row C: Initiated 500 ms after the first charge in Stratum 1 row F. Inter-hole delays of 50 ms are used in this layer in row C. This row is the first row to fire in this layer in order to provide initial breakage in the central zone and ensure minimal movement of the stand-up sections of the blast towards the free face.

Stratum 3: Row D: Initiated 100 ms after the first charge in Stratum 3 row C. Inter-hole delays of 50 ms are used in this layer in row D.

Stratum 3: Row A: Initiated 150 ms after the first charge in Stratum 3 row C. Inter-hole delays of 50 ms are used in this layer in row A.

Stratum 3: Row F: Initiated 150 ms after the first charge in Stratum 3 row D. Inter-hole delays of 50 ms are used in this layer in row F.

Stratum 3: Row G (presplit): Already initiated as described earlier.

Stratum 4: Row C: Initiated 200 ms after the first charge in Stratum 3 row F. Inter-hole delays of 50 ms are used in this layer in row C.

Stratum 4: Row D: Initiated 100 ms after the first charge in Stratum 4 row C. Inter-hole delays of 50 ms are used in this layer in row D.

Stratum 4: Row A: Initiated 50 ms after the first charge in Stratum 4 row D. Inter-hole delays of 50 ms are used in this layer in row A.

Stratum 4: Row F: Initiated 150 ms after the first charge in Stratum 4 row D. Inter-hole delays of 50 ms are used in this layer in row F.

Stratum 4: Row G (presplit): Already initiated as described earlier.

This multi blast will yield the following:

1. A layer of buffering material from stratum 1 row A in front of the main (bottom) coal seam.
2. A substantial proportion of material from stratum 1 rows B, C, D and E thrown into a final spoil position, due to the combination of high powder factors, shorter inter-hole

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delays and longer inter-row delays, with initiation proceeding from the free face backwards into the blast block.

3. A presplit forming a clean highwall at the back of the entire blast block.
4. Stand-up blasts within strata 3 and 4, designed with lower powder factors, central initiation, longer inter-hole delays and shorter inter-row delays in contrast to stratum 1, thus providing adequate breakage of material in strata 2, 3 and 4 to enable the excavation of the material and recovery of coal without substantial disruption or crushing of the coal seams, or dilution of the coal seams with the inter- or over-burden material.

Figure 7 shows an example of a multi-blast with specific designs for differential fragmentation outcomes within each of the separate layers. For convenience the same reference numerals will be used as in Figure 2 where appropriate. The same approach as used in Figures 6a and 6b will be used to identify rows of blastholes and individual blastholes within such rows. Figure 7 shows an overburden layer 50 on top of a recoverable mineral layer 52. While this example only shows two layers, several layers may be involved, each with similarly differential designs in order to achieve differential fragmentation outcomes.

The overburden layer 50 has a blast designed to result in finer fragmentation for increased excavation productivity. By contrast, the recoverable mineral layer 52 has a blast designed for coarser fragmentation to produce more "lump" material, which has a higher value for some minerals such as coal and iron ore. The use of different inter-hole and inter-row timing, as well as multiple in-hole initiation, all in combination with a higher powder factor in the overburden layer 50 as compared to that in the mineral layer 52, enable the differential fragmentation outcomes to be achieved.

In Figure 7, there are six rows A-F of blastholes a-f. In this example, only four rows, namely rows A, C, D, and F, extend into the mineral layer 52. The nominal blasthole diameter is 270 mm and the nominal burden distances between rows and spacing distances